A FMIPv6 Based Handover Scheme for Real-Time Applications in Mobile WiMAX

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Abstract—**The IEEE 802.16 standard was designed to provide rapid deployment, high bandwidth, and low-cost fixed broadband wireless access (BWA). As an enhancement, IEEE 802.16e standard was developed for further supporting mobility. As media streaming services are extending to mobile stations, it is crucial to minimize the handover delay and service disruption time so as to maintain the sustained connection of IP sessions. In this work, we propose a cross-layer IPv6 fast handover scheme which features integrated layer 2/layer 3 messages and fast network re-entry methods. Compared with the fast mobile IPv6 over 802.16e network scheme in predictive mode, our proposed scheme can reduce the service disruption time by more than 90% and 85% for downlink and uplink, respectively so that the quality of service (QoS) for real-time applications can be improved significantly.**

Index Terms—**cross-layer; IPv6; mobility; handover; WiMAX; QoS**

I. INTRODUCTION

The IEEE 802.16-2004 standard [1] defines the air interface specification for wireless metropolitan area network (WMAN) to support high speed data transmission. As the enhancement to the IEEE 802.16-2004, the IEEE 802.16e [2] provides a series of handover procedures to support mobility service in the worldwide interoperability for microwave access (WiMAX). Handover is the process of maintaining the active sessions of a mobile station (MS) as it migrates from the network served by one base station (BS) to the network served by another BS.

There are two categories of handover: the link layer handover and the IP layer handover, also known as layer 2 and layer 3 handover, respectively. The former is defined in IEEE 802.16e that includes three modes, a mandatory hard handover, also known as break-before-make; a macro diversity handover (MDHO) and a fast BS switching (FBSS). The last two are optional make-before-break soft handovers, in which an MS may register with several BSs simultaneously so it can achieve less handover latency. However, there are quite a bit of restrictions on the BS under these two modes, such as synchronization in a common timing source, same carrier frequency, and sharing of all information. Hence, the IEEE 802.16e uses the hard handover basically. The IP layer handover procedures comprising movement detection, new care of address (CoA) configuration, and binding update are handled by the Mobile IPv6 (MIPv6) [3].

If the serving BS and target BS involved in the handover locate in the same subnet, the MS only needs to perform link layer handover, which is regarded as an intra-domain handover. Otherwise, it is called an inter-domain handover, and the MS must re-configure a new IP address then execute both the link layer and IP layer handover.

Generally, in a handover procedure there are two types of time interval, the total handover delay and service disruption time (SDT). The former represents the time spent in both link layer and IP layer handover procedures. While the latter is the time interval during which the MS is unable to receive/send packets. SDT is caused by the hard handover and IP layer handover, and minimizing the SDT is a key issue in supporting seamless handover for real-time applications.

Several handover schemes have been proposed to improve the handover latency. In [4], new schemes including target BS selection, fast synchronization and association, and optimized handover initiation timing were presented to reduce the layer 2 handover delay. In [5], a network assisted fast handover scheme using the fast association and fast network re-entry methods was proposed to improve the layer 2 handover. These two studies focus on reducing the link layer latency. For decreasing both link and IP layer handover delays, several researches use the cross-layer designs [6, 7, 8, 9, 10]. The authors defined several events for supporting the interaction between the IP layer and the link layer handover procedures [6, 7]. The scheme in [8] uses a layer 3 tunnel between the serving BS and the target BS to redirect and relay the link layer messages such as ranging, capability negotiation, and registration during handover. Therefore the direct message transfer between the MS and the neighboring BSs can be minimized. In [9], the integrated design of the layer 2 and layer 3 handovers reduces the overhead of handover procedures. In [10], a

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fast key exchange and fast authentication procedure based on cross-layering design decreases the authentication time during the network re-entry procedures.

The above studies focus on reducing either the link layer delay or total handover delay without concerning the SDT. For delay sensitive real-time applications, minimizing the SDT will effectively improve their QoS. In this study, we propose a cross-layer IPv6 fast handover scheme based on the integrated layer 2/layer 3 messages and fast network re-entry methods. Through performance analysis, we demonstrate that our proposed scheme features much lower SDT and total handover delay than the fast mobile IPv6 over 802.16e network scheme.

II. BACKGROUND

IEEE 802.16e Handover Procedure

The IEEE 802.16e link layer handover process [2] consists of cell reselection, handover decision and initiation, synchronization to the target BS, ranging and network re-entry, and termination of context with previous BS. The detailed procedures are depicted in Fig. 1. To provide the network topology information and facilitate an MS to synchronize itself with the neighboring BSs, the serving BS periodically broadcasts a Mobile Neighbor Advertisement (MOB_NBR-ADV) message containing the channel information about the neighboring BSs. An MS may exchange the Mobile Scanning Request (MOB_SCN-REQ) and Mobile Scanning Response (MOB_SCN-RSP) messages with the serving BS and perform a scanning process to monitor and measure the radio condition of these neighboring BSs.

During the scanning process, the serving BS may buffer the incoming data destined to the MS and transmit them after the scanning. After the scanning process, the MS will select suitable ones from the candidate neighboring BSs for a future handover.

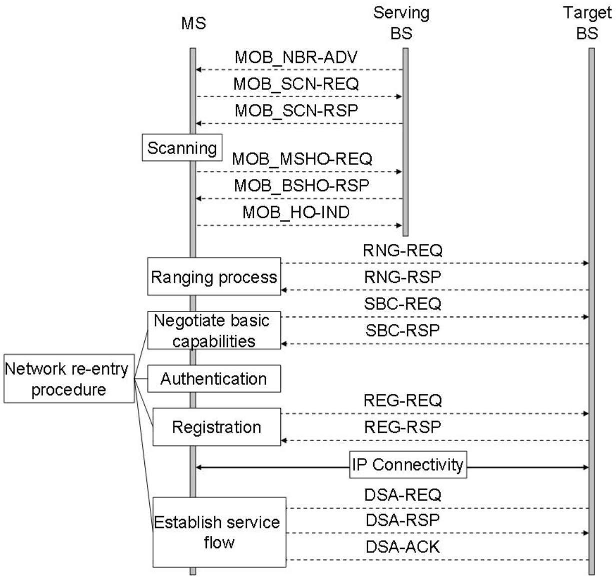

Figure1. The IEEE 802.16e handover procedure.

An MS or serving BS may decide to perform handover based on the signal strength or QoS parameters, and use a Handover Request message (MOB_MSHO-REQ) or (MOB_BSHO-REQ), respectively to initiate a handover. Upon receiving a MOB_MSHO-REQ message, which contains the candidate neighboring BSs selected by the MS, the serving BS will reply with the MOB_BSHO-RSP message that contains the recommended BSs based on the information in the MOB_MSHO-REQ message. In this study, we assume that the handover procedure is initiated by an MS.

Once switched to the target BS, the MS has to perform the ranging and 802.16e network re-entry processes. There are four steps in the 802.16e network re-entry procedure, negotiation of basic capabilities, authentication, registration, and establishing service flows. Their detailed messages are displayed in Fig. 1. In order to accelerate the network re-entry procedure, the target BS may negotiate with the serving BS to obtain the information of the MS over the backbone network after receiving a RNG-REQ message which contains a base station identifier (BSID) of the serving BS. Following the registration of the MS with the target BS, the target BS will become a new serving BS. After the network re-entry process is completed, the connection between the MS and the target BS will be established. Moreover, the MS should obtain some connection identifiers (CIDs) and associated bandwidth allocations for transmission. However, when the MS moves to a different subnet, it should re-configure a new IP address and re-establish an IP connection. Additionally, the MS should perform an IP layer handover to resume the active session of the previous connection. To reduce the time latency of the IP layer handover, the fast mobile IPv6 handover procedure for executing in the MS has been developed.

Fast Mobile IPv6 Handover Procedure over IEEE 802.16e network

MIPv6 [3] is able to handle the IP handover between subnets and thus provides the session continuity during handover. However, for streaming traffic such as Voice over IP (VoIP), the handover delay resulted from the MIPv6 process which comprises movement detection, new CoA configuration, and binding update is often unacceptable [11]. In order to reduce the handover delay, the Fast Mobile IPv6 handover protocol (FMIPv6) has been developed. For movement detection, the FMIPv6 enables an MS to quickly detect its entering to a new subnet through providing the new BSID. Regarding new IP address configuration, the FMIPv6 allows an MS to obtain the newly associated subnet prefix information when it is still connecting to the current subnet.

Fig. 2 illustrates the FMIPv6 handover procedure over IEEE 802.16e network [7]. An MS learns the network topology and obtains the link information through listening to the periodic MOB_NBR-ADV message from its serving BS. Then it may perform the scanning process. Once an MS finds a new BS through the methods described above, a Link_Detected (LD) event will be triggered by the link layer to notify the IP layer to exchange the Router Solicitation for Proxy (RrSolPr) and

Proxy Router Advertisement (PrRtAdv) messages with the previous access router (PAR) to obtain the associated access router (AR) information of the new BS and produce a list of [BSID, AR-Info] tuple(s). The AR Information (AR-Info) that contains the associated AR's prefix information, IP address, and link layer address can be used to configure a new CoA.

A Link_Handover_Imminent (LHI) event will be triggered after the MS sends a MOB_MSHO-REQ message to initiate the handover procedure and then receives a MOB_BSHO-RSP message containing the recommended BSs as a response. This event indicates that a link layer handover decision has been made and an impending handover is coming. It also forces the IP layer to send a Fast Binding Update (FBU) message to the PAR. Upon receiving an FBU message, the PAR exchanges the Handover Initiation (HI) and Handover Ack (HAck) messages with the target AR to confirm the new CoA (i.e. duplicate address detection (DAD) procedure) and set up a tunnel between the previous CoA and new CoA. Next, the PAR will forward the packets destined to the previous CoA to the new one as well as send back a Fast Binding Acknowledge (FBAck) message to the MS. The target AR will buffer these packets until receiving a Fast Notification (FNA) message from the MS. In order to force the MS to switch from the current BS to the target BS, a Handover_Commit (HC) event triggered by the receipt of the FBAck message will inform the link layer to issue a MOB_HO-IND message.

As the MS performs the ranging process and completes the 802.16e network re-entry procedure after switching to the target BS, it will trigger a Link_Up (LU) event indicating that the MS has established the link layer connection with the target BS, the LU will force the IP layer to send a FNA message to the new AR (NAR). When the NAR receives a FNA message, it will deliver the buffered packets to the MS.

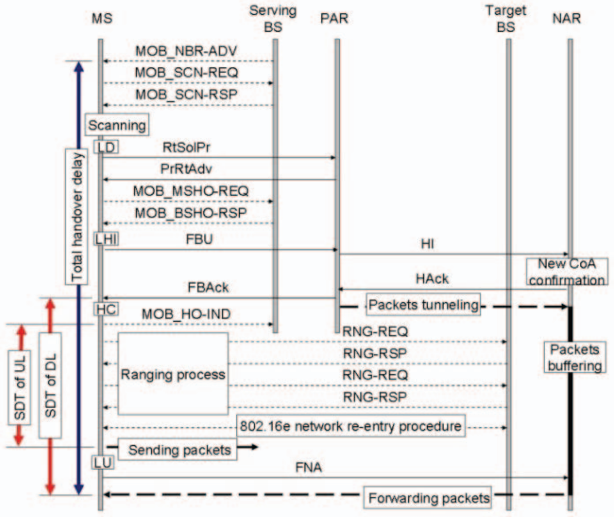

Figure 2. FMIPv6 handover procedure over IEEE 802.16e network.

In case the MS receives an FBAck message before starting the link layer handover, i.e. receiving an FBAck message before the MS sends a MOB_HO-IND message, the MS will operate in the predictive mode, which enables the MS to quickly receive packets from the NAR after it has moved to the NAR. On the contrary, if the MS finished the link layer handover before it acquires an FBAck message on the current link, it should operate in the reactive mode. In this situation, the MS must issue an FNA message that encapsulates the FBU message to the NAR, which will then verify the availability of the new CoA and forward the inner FBU message to the PAR to establish a tunnel.

III. A CROSS-LAYER IPV6 FAST HANDOVER SCHEME FOR IEEE 802.16E NETWORK

In this work, a cross-layer IPv6 fast handover network architecture for IEEE 802.16e was proposed to reduce the time latency caused by the 802.16e layer 2 and FMIPv6 layer 3 handover procedures. Before the ranging process, the serving BS can be forced to negotiate with the candidate target BSs to acquire new CIDs for the MS. The downlink packets can be transmitted after the new serving BS receives a FNA-RNG-REQ message, and the uplink packets can be sent by an MS after it finishes the ranging process. Moreover, the redundant messages can be avoided by integrating the link layer and IP layer messages. Thus, the total handover latency and SDT can be reduced.

Integration of Layer 2 and Layer 3 Messages

According to the IEEE 802.16e and FMIPv6 handover processes, an MS must periodically listen to the MOB_NBR-ADV message from its serving BS to obtain the information of the neighboring BSs. Based on either the signal strength or QoS parameters of the neighboring BSs obtained via scanning process, the MS may select some candidate BSs for potential handover. Next, the MS will request the corresponding ARs' information of the candidate BSs to re-configure new CoAs via exchanging the RtSolPr and PrRtADV messages. By integrating the MOB_NBR-ADV message with the PrRtADV message, the MS can simultaneously obtain the information of the BSs and corresponding ARs. The new integrated message is called Pr-MOB_NBR-ADV.

While moving to the target BS, the MS will perform initial ranging process with the target BS to obtain the relative timing and power-level adjustment required for maintaining the uplink connection through sending a RNG-REQ message first. This implies that the MS has moved to a new network, thus, the MS can notify the NAR via the FNA message to forward the buffered packets to it. In our proposed method the target BS will transmit the FNA message to the NAR upon receiving the FNA-RNG-REQ message, instead of sending a FNA message by the MS. By integrating these messages, certain messages become redundant and can be eliminated, thus the total handover latency can be reduced.

Fast Network Re-entry Scheme

Before an MS resumes receiving/sending packets, it must complete the network re-entry procedure. In order to simplify the steps of the 802.16e network re-entry procedure, the serving BS may coordinate with the target BS over the backbone [2]. However, the process only can be performed after the MS switches to the target BS. Therefore, the SDT is dramatically long.

Based on the fast network re-entry scheme proposed here, after the serving BS receives a MOB_MSHO-REQ message which contains the candidate target BSs selected by the MS for future handover, it will issue a HO_notification-REQ message to negotiate with these candidate target BSs regarding the information of the MS. The HO_notification-REQ message contains the parameters of the initial ranging process, basic capabilities, authorization, registration, service flow construction, and QoS. As a candidate target BS obtains these parameters, both an opportunity for unicast ranging and the new CIDs for traffics will be provided to the MS. Note that the candidate target BS only allocates the bandwidth for ranging process of the MS at the moment, while the bandwidth allocations for actual traffics will not be available until the MS sends a FNA-RNG-REQ message to indicate its arrival. Furthermore, the candidate target BS starts a timer for retaining the resources. The serving BS will get the results from these candidate target BSs through a HO_notification-RSP message. Then, the serving BS forwards the results to the MS through the MOB_BSHO-RSP message.

Upon receiving a MOB_HO-IND message, the serving BS will issue a HO_Decision message to notify these candidate target BSs (except the target BS) the final choice of the MS. The resources retained for the MS will be released upon the expiration of the timer or receipt of a HO_Decision message. The network re-entry procedures will be finished in advance through negotiating with these candidate target BSs before disconnecting from the serving BS. The MS can receive packets immediately after sending a FNA-RNG-REQ message to inform the target BS its arrival and send packets after completing the ranging process. Moreover, the MS can issue the FNA-RNG-REQ message without competition because it owns a dedicated time slot for ranging process. Thus, the SDT for downlink (DL) and uplink (UL) can be minimized.

Procedure of proposed scheme

There are two situations to be considered in the proposed scheme depending on the occasion of receipt of the FBAck message. Fig. 3 and Fig. 4 illustrate these two situations respectively and the detailed steps are described below.

[Predictive mode]

1. The serving BS broadcasts a Pr-MOB_NBR-ADV message periodically.
2. The MS obtains the information of neighboring BSs with associated ARs, then it generates a list of [BSID, AR-Info] tuple(s), starts the configuration of CoA, and performs the scanning process to find suitable BSs for handover.
3. To initiate a handover, the MS sends a MOB_MSHO-REQ message which contains a list of the candidate BSs.
4. The serving BS negotiates with these candidate BSs through exchanging the HO_notification-REQ and HO_notification-RSP messages. After this step, these candidate BSs begin to retain resources for the MS.
5. The serving BS informs the MS the negotiated result via a MOB_BSHO-RSP message.
6. The link layer triggers an LHI event to the IP layer after the MS receives a MOB_BSHO-RSP message.
7. Upon detecting the LHI event, the IP layer will transmit an FBU message to the PAR.
8. As the PAR receives an FBU message from the MS, it will exchange the HI and the HAck messages with the NAR to establish a tunnel and confirm the new CoA. Next, the PAR sends back an FBAck message to the MS. The packets destined to the previous CoA will be forwarded to the new CoA after the tunnel is established.
9. Upon receiving the FBAck message the IP layer will trigger an HC event to the MAC layer.

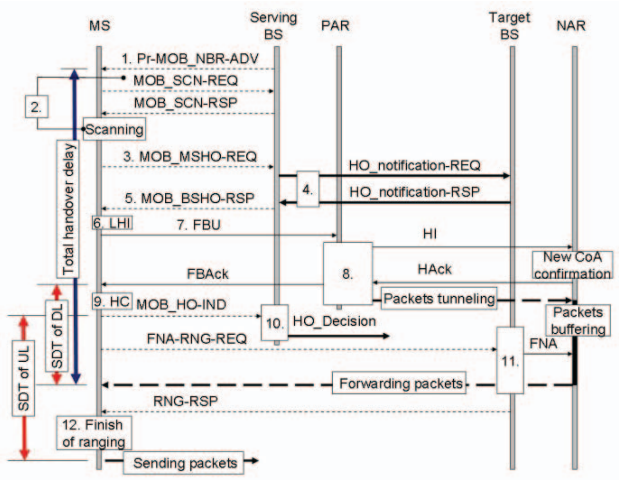

Figure 3. The predictive mode with the proposed scheme.

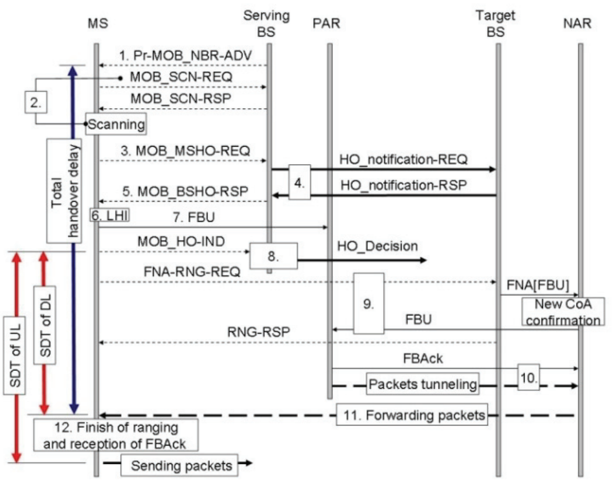

Figure 4. The reactive mode with the proposed scheme.

10. The HC event forces the MAC layer to send a MOB_HO-IND message to the serving BS to disconnect the link. While the serving BS receives this message, it will issue a HO_Decision message to notify these candidate target BSs (except the target BS) to cancel the resources retained for the MS.
11. The MS with a dedicated time slot for ranging process sends a FNA-RNG-REQ message to the target BS to inform its arrival. After receiving this message, the target BS begins to allocate bandwidth for the MS. Next, it sends a FNA message to inform the NAR to deliver buffed packets, and the MS can receive packets at this moment.
12. After completing the ranging process for adjusting the UL transmission power, the MS can start sending the packets.

[Reactive mode]

1-7. These are same as the predictive mode described above.

8. The MS sends the FBU message to the PAR. However, due to the low signal strength of serving BS, the MS transmits a MOB_HO-IND message to the serving BS before it receives the FBAck message. The serving BS will issue a HO_Decision message to notify these candidate target BSs except the target BS to release the resources retained for the MS as it receives the MOB_HO-IND message.
9. The MS with a dedicated time slot for ranging process sends a FNA-RNG-REQ message to the target BS to inform its arrival. Upon receiving this message, the target BS will begin to allocate bandwidth for the MS and send an FNA[FBU] message to NAR. Next, the NAR will confirm the new CoA and forward the inner FBU message to the PAR.
10. As the PAR receives an FBU message, it will establish a tunnel with the NAR and send back the FBAck message to the MS. After the tunnel is established, the packets destined to the previous CoA will be forwarded to the new CoA.
11. The NAR will deliver these packets to the MS once it receives the tunneled packets from the PAR, and the MS can receive packets thereafter.
12. The MS can send packets after finishing the ranging process and receiving the FBAck message which confirms a successful new CoA.

IV. PERFORMANCE ANALYSIS

We perform a message based performance analysis instead of the process based approach used in [12]. Before analyzing the delay performance, we define the time intervals during handover procedures. The total handover delay starts with the transmission of a MOB_NBR-ADV message, and ends with the receipt of a packet by the MS in the target BS. The SDT can be viewed from both DL and UL. The SDT of DL is defined as the elapsed time experienced by an MS from its receiving the last packet through its PAR to its receiving the first packet through the NAR via a tunnel. As the PAR establishes a tunnel with the NAR, the packets destined to previous CoA will be forwarded to the new CoA. Hence, in the predictive mode, the MS can't receive packets from the PAR after receiving an FBAck message. On the contrary, in the reactive mode, the MS can't receive packets after sending a MOB_HO_IND message. The SDT of UL is defined as the elapsed time experienced by an MS from its sending the last packet through its PAR to its sending the first packet through the NAR. In the predictive mode, SDT starts with the transmission of a MOB_HO-IND message, and ends with finishing the ranging process. While in the reactive mode, SDT starts with the transmission of a MOB_HO-IND message, and ends with the finish of ranging process and receipt of an FBAck message via tunnel.

The total handover delay and SDT of DL/UL for the FMIPv6 over 802.16e network mechanism (FM802.16e) and the proposed scheme are shown in Fig. 2, 3, and 4.

Some parameters were defined for the analysis in Table 1, and the topology considered for performance analysis and simulation is presented in Fig. 5.

TABLE I.
PARAMETERS FOR PERFORMANCE ANALYSIS

Parameter	Description	Values
T_{frame}	Frame duration of IEEE 802.16	5 ms
T_{cont_resol}	Latency of contention resolution procedure during contention based ranging process.	50 ms
T_{rng}	Latency of ranging process. It usually needs at least six frames.	30 ms
T_{L2_entry}	Latency of IEEE 802.16 network re-entry procedure	200 ms
T_{hop}	Latency of every routing hop in wired backbone network	0.5 ms
T_{dad}	Latency of DAD procedure (New)	1 s
T_{bs_ar}	Transmission delay between BS and AR	1 ms
N_{par_nar}	Number of hop between PAR and NAR	2 hops
D_{olap}	Overlap distance between Serving and Target BS	35 m
v	Velocity of MS	-

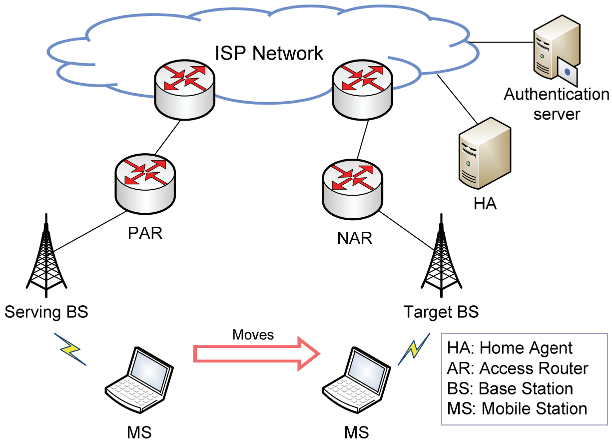

Figure 5. The network topology.

Message transmission delay between serving BS and MS is T_{frame}, and between PAR and MS is $T_{frame}+ T_{bs\_ar}$. Therefore, in predictive mode, the total handover delay with both FM802.16e and proposed schemes can be expressed by (1) and (2) respectively.

$$12T_{frame} + 6T_{bs_{ar}} + 2 \times \left(N_{par_{nar}} + 1\right) \times T_{hop} + T_{dad} + T_{cont_{resol}} + T_{rng} + T_{L2_{entry}} \tag{1}$$

$$10T_{frame} + 8T_{bs\_ar} + 4 \times \left(N_{par\_nar} + 1\right) \times T_{hop} + T_{dad} \tag{2}$$

Similarly, if we assume MS can receive FBAck and first tunneled packet at the same time, the total handover delay with both FM802.16e and proposed schemes in reactive mode can be expressed as (3) and (4).

$$11T_{frame} + 5T_{bs_{ar}} + 2 \times \left(N_{par_{nar}} + 1\right) \times T_{hop} + T_{dad} + T_{cont\_resol} + T_{rng} + T_{L2\_entry} \tag{3}$$

$$9T_{frame} + 7T_{bs\_ar} + 4 \times \left(N_{par\_nar} + 1\right) \times T_{hop} + T_{dad} \tag{4}$$

In predictive mode, the SDT of DL/UL with both schemes can be expressed as follows:

- SDT of DL with the FM802.16e:

$$3T_{frame} + 2T_{bs\_ar} + T_{cont\_resol} + T_{rng} + T_{L2\_entry} \tag{5}$$

- SDT of DL with the proposed scheme:

$$3T_{frame} + 2T_{bs\_ar} \tag{6}$$

- SDT of UL with the FM802.16e:

$$T_{frame} + T_{cont\_resol} + T_{rng} + T_{L2\_entry} \tag{7}$$

- SDT of UL with the proposed scheme:

$$T_{frame} + T_{rng} \tag{8}$$

In the reactive mode, SDTs were expressed as follows:

- SDT of DL with the FM802.16e:

$$3T_{frame} + 2T_{bs\_ar} + 2 \times \left(N_{par\_nar} + 1\right) \times T_{hop} + T_{cont\_resol} + T_{rng} + T_{L2\_entry} + T_{dad} \tag{9}$$

- SDT of DL with the proposed scheme:

$$3T_{frame} + 2T_{bs\_ar} + 2 \times \left(N_{par\_nar} + 1\right) \times T_{hop} + T_{dad} \tag{10}$$

- SDT of UL with the FM802.16e:

$$3T_{frame} + 2T_{bs\_ar} + 2 \times \left(N_{par\_nar} + 1\right) \times T_{hop} + T_{cont\_resol} + T_{rng} + T_{L2\_entry} + T_{dad} \tag{11}$$

- SDT of UL with the proposed scheme:

$$3T_{frame} + 2T_{bs\_ar} + 2 \times \left(N_{par\_nar} + 1\right) \times T_{hop} + T_{dad} \tag{12}$$

SDT is affected by the velocity of MS. If the MS moves very fast, it won't receive FBAck message before it has to send MOB_HO-IND message as a final indication of handover. As a result, the handover process has to operate in reactive mode that may cause longer SDT. Therefore, the overlap distance between two BSs affects SDT. When MS is moving in the overlap area, it performs the handover preparation and handover decision and initiation procedures. At the edge of this area, MS must execute the handover process. So the relation among overlap distance, velocity of MS and handover preparation latency (T) can be expressed as (13).

$$D_{olap} \geq v \times \mathrm{T} \tag{13}$$

Fig. 6 shows the total handover delay and SDT in both modes of proposed scheme and FM802.16e scheme, and the effect of the MS's velocity on the SDT of the proposed scheme and FM802.16e scheme is shown in Fig. 7. We can clearly observe that the SDT and total handover delay of proposed scheme in both modes are smaller than that in FM802.16e scheme because the network re-entry procedure was accomplished in advance and the contention-free ranging process.

On the other hand, the SDT of DL is lower than that of UL with proposed scheme in the predictive mode because packets can be forwarded to MS after it sends an FNA-RNG-REQ message without waiting for finish of ranging process. Besides, in reactive mode, the SDTs with both FM802.16e and proposed schemes are larger than 1000 ms due to the long DAD procedure.

In proposed/FM802.16e scheme, MS has enough time to initiate fast handover in predictive mode for velocity of MS up to 120/115 km/h, but it has to switch to the reactive mode over 120/115 km/h. Hence, MS almost can perform handover procedure in predictive mode even it moves with a vehicle speed.

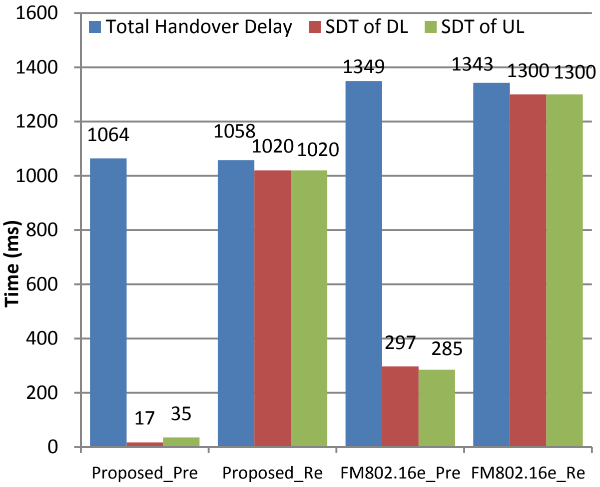

Figure 6. Total handover delay and SDT

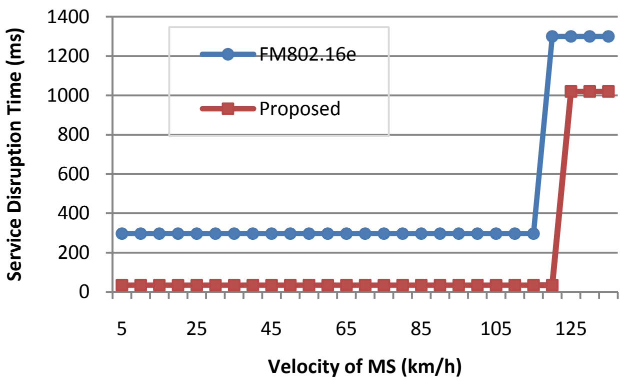

Figure 7. SDT in terms of velocity

V. SIMULATION RESULTS

We perform simulation using NS-2 (version 2.33) simulation tool [13] with Seamless and Secure Mobility Module which is designed and developed by the National Institute Standards and Technology (NIST) [14]. Also we use Light WiMAX Simulator (LWX) Module [15] which supports IEEE 802.16 and IEEE 802.16j.

In this simulation, the MS moves from serving BS to target BS that belongs to different IP subnets in the same ISP network, and it receives and transmits a downlink and an uplink VoIP traffic respectively. The VoIP traffic rate is 64 Kbps and the packet size is 200 bytes. The uplink VoIP and downlink VoIP begins at 0 second and at 0.5 second respectively. Both traffics end at 3 second.

MS disconnects with serving BS at 2.0551 second in predictive mode and 1.0351 second in reactive mode respectively. Fig. 8 to Fig. 11 show the simulation results. We can find higher downlink packet loss rate in reactive mode because of no buffering mechanism and long SDT which is larger than 1 second. However, in reactive mode the SDT of the proposed scheme is still less than that of FM802.16e.

In Fig. 8 and 10, we can observe that the SDT of proposed scheme is about 0.025 second in DL and 0.040 second in UL. On the other hand, the SDT of FM802.16e is about 0.3 second in DL and 0.290 second in UL. And due to the buffering mechanism, there is no packet loss in predictive mode.

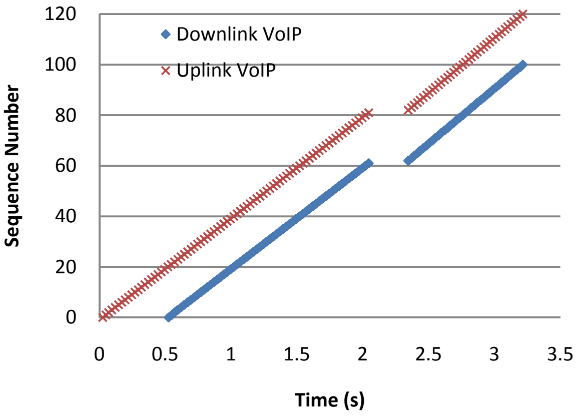

Figure 8. Packet sequence numbers in FM802.16e predictive mode

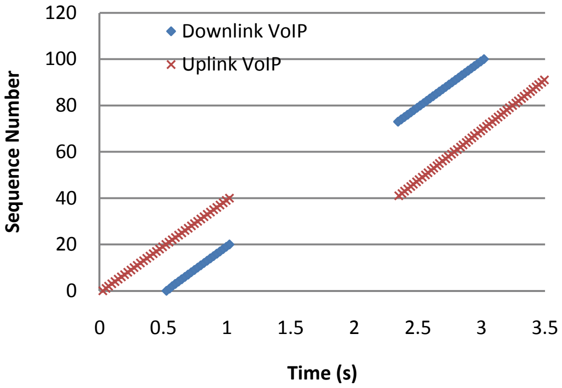

Figure 9. Packet sequence numbers in FM802.16e reactive mode

Table 2 shows the total handover delay and SDTs. The simulation results are almost the same as the performance analysis. In our proposed scheme, The SDT of DL and UL are both less than 40 ms. Compared with the FM802.16e, the SDT of DL can be reduced by 91.67%, and UL by 86.25% in the predictive mode. Regarding the reactive mode, our proposed scheme reduces the SDT of DL and UL by 20.53% and 20.85% respectively. On the other hand, our proposed scheme reduces total handover delay by about 20.77%.

The results shows that our proposed scheme features much shorter total handover delay and SDT of DL/UL, therefore it can significantly improve the QoS for real-time applications during handover in IEEE 802.16e networks.

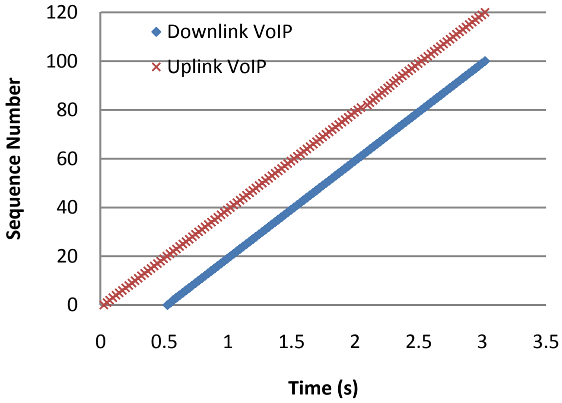

Figure 10. Packet sequence numbers in proposed predictive mode

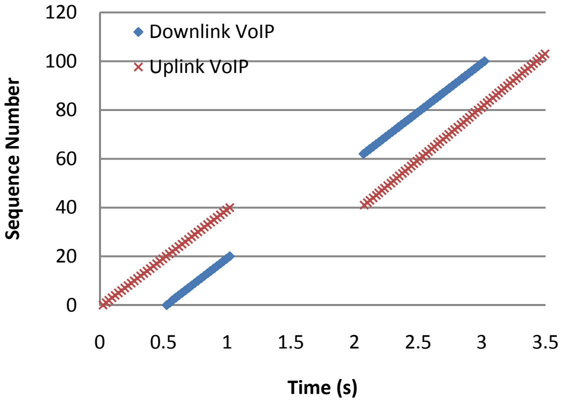

Figure 11. Packet sequence numbers in proposed reactive mode

TABLE II.
TOTAL HANDOVER DELAY AND SDTS IN BOTH SCHEMES

	Total handover delay		SDT			
			Predictive		Reactive	
	Predictive	Reactive	DL	UL	DL	UL
FM802.16e	1345 ms	1346 ms	300 ms	291 ms	1325 ms	1314 ms
Proposed	1069 ms	1063 ms	25 ms	40 ms	1053 ms	1040 ms

VI. CONCLUSIONS

In this study, we propose a cross-layer IPv6 fast handover network architecture for IEEE 802.16e to accommodate the delay sensitive real-time applications. The total handover delay and SDT were reduced by integrating the link layer and IP layer messages and using a fast network re-entry mechanism. The performance analysis result showed that our proposed scheme features much smaller SDT than the FMIPv6 over 802.16e scheme. As a result of a small SDT, the impact of handover on real-time services can be minimized.

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